Title	A systematic review and meta-analysis of energy intake and weight gain in pregnancy
Author(s)	Jebeile, H; Mijatovic, J; Louie, CYJ; Prvan, T; Brand-Miller, JC
Citation	American Journal of Obstetrics and Gynecology, 2016, v. 214 n. 4, p. 465-483
Issued Date	2016
URL	http://hdl.handle.net/10722/223304
Rights	© 2016. This manuscript version is made available under the CC-BY-NC-ND 4.0 license http://creativecommons.org/licenses/by-nc-nd/4.0/; This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License.

A systematic review and meta-analysis of energy intake and weight gain in pregnancy

***Ms Hiba JEBEILE, MNUTRDIET, *Ms Jovana MIJATOVIC, MNUTRDIET, Dr Jimmy Chun Yu LOUIE, PHD, Dr Tania PRVAN, PHD, Dr Jennie C BRAND-MILLER, PHD**

School of Molecular Bioscience and Charles Perkins Centre, The University of Sydney, Camperdown 2006 NSW Australia (HJ, JM, JCYL, JCBM)

Department of Statistics, Faculty of Science and Engineering, Macquarie University, Sydney 2109 NSW Australia (TP)

***Equal contribution from these authors**

Author surnames: JEBEILE, MIJATOVIC, LOUIE, PRVAN, BRAND-MILLER

Source(s) of support: No external funding was required to facilitate this research or preparation of the manuscript

Conflict of interest statement: The authors report no conflict of interest.

Corresponding author

Professor Jennie C Brand-Miller

Level 6 West, The Hub

D17 Charles Perkins Centre

The University of Sydney NSW 2006

Australia

Ph: +61 2 93513759

E: jennie.brandmiller@sydney.edu.au

Reprints will not be available

Abbreviations: BMI, body mass index; BMR, basal metabolic rate; GDM, gestational diabetes mellitus; GWG, gestational weight gain; IOM, Institute of Medicine; PAL, physical activity level; RCT, randomized controlled trial; SD, standard deviation; SMD, standardized mean difference; t, time point

Word count: Abstract = 333 words; Main text = 3480 words

Number of tables and figures: 2 and 5 respectively

Condensation: Women report little or no change in energy intake during pregnancy

Running head: Energy intake and weight gain in pregnancy

ABSTRACT

BACKGROUND: Gestational weight gain within the recommended range produces optimal pregnancy outcomes, yet many women exceed the guidelines. Official recommendations to increase energy intake by ~ 1000 kJ/day in pregnancy may be excessive.

OBJECTIVE: To determine by meta-analysis of relevant studies whether greater increments in energy intake from early to late pregnancy corresponded to higher or excessive gestational weight gain.

DATA SOURCES: We systematically searched electronic databases for observational and intervention studies published from 1990-present. The databases included Ovid Medline, Cochrane Library, Excerpta Medica DataBASE (EMBASE), Cumulative Index to Nursing and Allied Health Literature (CINAHL) and Science Direct. In addition we hand searched reference lists of all identified articles.

STUDY ELIGIBILITY CRIETRIA: Studies were included if they reported gestational weight gain and energy intake in early and late gestation in women of any age with a singleton pregnancy. Search also encompassed journals emerging from both developed and developing countries.

STUDY APPRAISAL AND SYNTHESIS METHDOS: Studies were individually assessed for quality based on the Quality Criteria Checklist obtained from the American Dietetic Association Evidence Analysis Manual. Publication bias was plotted using a funnel plot with standard mean difference against standard error. Identified studies were meta-analyzed and stratified by Body Mass Index, study design, dietary methodology and country status (developed/developing) using a random-effects model.

RESULTS: Of 2487 articles screened, 18 studies met inclusion criteria. On average, women gained 12.0 (2.8) kg (Standardized Mean Difference = 1.306, $P < 0.0005$) yet reported only a small increment in energy intake that did not reach statistical significance (~475 kJ/day, Standard Mean Difference = 0.266, *P* = 0.016). Irrespective of baseline Body Mass Index, study design, dietary methodology or country status, changes in energy intake were not significantly correlated to the amount of gestational weight gain (r = 0.321, *P* = 0.11).

CONCLUSION: Despite rapid physiological weight gain, women report little or no change in energy intake during pregnancy. Current recommendations to increase energy intake by ~ 1000 kJ/day may therefore encourage excessive weight gain and adverse pregnancy outcomes.

KEYWORDS: energy intake; first trimester; gestational weight gain; pregnancy; third trimester

INTRODUCTION

In developed nations, one third or more of women of childbearing age are overweight or obese [1-3]. Excessive pre-conception body weight is a recognized risk factor for adverse pregnancy outcomes, including gestational diabetes mellitus (GDM), pregnancy-induced hypertension, pre-eclampsia and caesarean delivery [4]. Maternal obesity is also linked with increased risk of macrosomia [3], stillbirth [5], pre-term birth [6] and congenital malformation [7]. Offspring of overweight and obese women are at increased risk of obesity in childhood and young adulthood, thereby creating an intergenerational vicious cycle [8-10].

Restricting or optimizing gestational weight gain (GWG) is one of the few interventions that can reduce adverse pregnancy outcomes [11]. The Institute of Medicine (IOM) specifies ranges of desirable weight gain for underweight, normal weight, overweight and obese pregnant women that have been adopted by other countries [12]. However, many pregnant women gain more than is optimal [13] and find it difficult to lose the excess weight post-pregnancy [14].

A logical assumption is that additional food intake is required to achieve the desirable rate of weight gain in pregnancy. Indeed, mathematical models have been developed to determine the theoretical additional energy costs involved in pregnancy [15]. The cumulative absolute cost for women with a normal BMI and a mean GWG of 12.0 kg has been estimated to be ~320 MJ, distributed as an additional 0-300 kJ/day in the first trimester, 1000-1500 kJ/day in the second, and 1800-2100 kJ/day in the third [16]. Nonetheless, energy requirements during pregnancy will be influenced by multiple factors, including pre-pregnancy weight, BMI, maternal age, stage of gestation, rate of GWG and increases in energy expenditure relating to an increase in body mass, and hence basal metabolic rate (BMR) [17,18].

Despite the theory, recent studies suggest that the current generation of women consume very little additional food energy to sustain a healthy pregnancy. A meta-analysis of 23 studies in well-nourished women reported an average increase of only ~140 kJ/day, i.e. a small fraction of the theoretical calculation or current recommendations [17]. It is conceivable that pregnant women now require less energy than earlier generations due to reductions in incidental physical activity and increasing sedentariness [19]. Pregnancy guidelines that recommend an additional 2000 kJ/day in the third trimester may result in excessive GWG and adverse pregnancy outcomes.

In this analysis, our objective was to determine whether a greater increment in reported energy intake from early to late pregnancy corresponded to higher or excessive GWG. We systematically searched for observational and randomized controlled trials published over the past 25 years that reported GWG along with energy intake in early and late pregnancy.

METHODS

Search Strategy

A systematic literature search was undertaken in August-October 2014 by 2 independent student dietitians (JM and HJ). A starting date of 1990 was specified so that the outcomes reflected the current generation of women whose pregnancy advice may have been influenced by IOM guidelines [20]. We searched Ovid Medline, Cochrane Library, Excerpta Medica DataBASE (EMBASE), Cumulative Index to Nursing and Allied Health Literature (CINAHL) and Science Direct for studies that reported energy intake in early and late pregnancy and GWG in singleton pregnancies in women of any age. Randomized controlled trials (RCT) and observational, cohort and longitudinal studies were eligible for inclusion. The following search terms were employed: “pregnant” OR “pregnancy” OR “pregnant woman” OR “gestation” OR “maternal” AND “energy intake” OR “macronutrient” OR “dietary fat” OR “dietary proteins” OR “dietary carbohydrate” OR “dietary intake” OR “calorie intake” OR “kilojoule intake” AND “weight gain” OR “body weight” OR “weight change” OR “body mass index” OR “BMI”. Hand-searching was conducted to identify additional studies. Studies reported as withdrawn in the database, and retrospective studies that preceded 1990, were excluded.

Study Selection

Full term pregnancy was defined as 37 – 42 weeks gestation [21]. Women were classed as underweight, normal, overweight and obese category according to IOM criteria. Countries were classified as ‘developed’ or ‘developing’ based on the United Nations criteria [22]. In relation to energy intake, early and later pregnancy were defined by timepoints (t_1 and t_2) at least 12 or more weeks apart, where t_1 <18 weeks and t_2 >30 weeks gestation (studies reporting data at intervals <12 weeks were excluded). GWG was recorded as the mean ± SD, where data was collected at <18 weeks (t_1) and >34 weeks gestation (t_2), except in 2 studies [23,24] where the value was calculated as the difference in weight at the 2 timepoints and the SD was calculated [25]. Studies published in a language other than English were excluded if a translation was not available. In the RCT, the control and intervention groups were analyzed as separate groups. Efforts were made to contact authors for additional data regarding their respective studies.

Data extraction

Data were independently extracted using standardized forms in the Excel spreadsheet which collected information on author, title, study type, year published, quality rating, population characteristics (country, age, number of participants, BMI, parity), dietary collection method, weeks gestation at time of data collection, energy intake at two time points (t_1 and t_2), macronutrient intake (g or % energy), weight (t_1 and t_2), and GWG. Data were cross-checked for accuracy and discrepancies resolved through discussion or involvement of a third party (JBM or JCYL).

Statistical analysis

The primary outcome measures were standardized mean difference (SMD) in energy intake and GWG from early to late pregnancy. Data were meta-analyzed collectively and stratified by developed and developing countries, BMI (underweight, normal, overweight and obese), study design (observational and RCT) and dietary assessment methodology. A random-effect model assumed heterogeneity among studies. The Mood's median test was used to test the equality of medians of SMD for energy intake and weight gain between developed and developing countries. Because of small sample sizes within each BMI group, the median GWG and interquartile range were used to assess mean weight gain compared to the IOM recommendations. To calculate SMDs of mean weight gain between 2 timepoints ($t_{1\text{ and }}t_2$), a Spearman correlation coefficient of 0.85 was applied [26]. Similarly for the 26 subgroups with reported energy intake at $t_{1\text{ and }}t_2$, a Spearman correlation coefficient of 0.74 was assumed. For the studies which provided a range for weight rather than SD, a value was imputed where r = 0.85. Analyses were repeated using r = 0.8 or 0.9 and r = 0.7 or 0.8 for weight and energy respectively did not alter findings. Data were analyzed using Comprehensive Meta-Analysis (CMA) package, version 2.2 (Biostat, Englewood, New Jersey, USA), and presented in the form of forest plots. *P*-values of < 0.01 were considered statistically significant as 7 comparisons were made in this study including Body Mass Index, country's economic status, dietary collection method, study type, energy intake, macronutrient distribution and gestational weight gain. This was achieved using Bonferroni correction, which divides the original *P* = 0.05 by the number of estimates made, producing a new *P*-value = 0.007, which was rounded to 0.01.

Assessment of Risk of Bias

Studies were individually assessed at a study level for bias and quality based on the Quality Criteria Checklist obtained from the American Dietetic Association Evidence Analysis Manual [27]. Only the studies which obtained a positive or neutral rating were included. Publication bias was assessed by developing a funnel plot using standard difference in means and standard error as x and y-intercepts respectively.

RESULTS

The electronic search revealed 2440 articles with a further 47 identified by hand-searching. Of these, 2301 did not meet inclusion criteria, in the main because they did not report energy intake at 2 time points at least 12 weeks apart. Three potential studies were excluded because of missing data [28-30]. The screening and selection process resulted in 18 studies of 2644 women published between 1992 and 2013 (**Figure 1**). Fourteen studies were observational studies [23,24,31-42], most conducted in a representative population with a mean BMI in the normal range. One study [41] was in an overweight population and 1 study [33] reported data by BMI category. Of the 4 RCTs [43-46], 1 was an intervention in an overweight population [44], and 2 in an obese population [43,46], all aimed at limiting GWG. One study [45] had a population group with a mean BMI in the normal range with interventions comparing pregnancy outcomes on a low GI diet vs healthy eating advice.

Of the 18 studies that met inclusion criteria, 2 obtained a positive quality rating and 16 were neutral (**Table 1**). Within studies, the number of study participants ranged from 10 to 620, with a mean (SD) age 29.6 (1.7) years, and BMI 25.3 (4.9) kg/m^2. Seven studies had a retention rate of >82% [32,35,36,38,39,41,45], 6 ranged 63-78% [23,31,34,42,43,46], 1 of 55% [33] and 3 did not report [24,37,40]. Sixteen subgroups reported total weeks gestation with an average of 39.6 (0.43) weeks. Only 6 studies reported parity mean = 1.8 (2.32). Dietary data, was collected on average at 12 (2.6) weeks and 35 (2.1) weeks gestation. The most frequent dietary collection method was a weighed or estimated food record (*n* = 18), but 3 studies used a food diary, 2 employed repeat 24-hr recall and 2 used a diet history. Characteristics of the included studies are summarized in **Table 2**.

Mean reported energy intake in the 18 studies was 8130 (1100) kJ/day and 8600 (1230) kJ/day in early and late pregnancy respectively. The SMD between the 2 was 0.266 (*P* = 0.016), a difference equivalent to ~475 kJ/day which did not reach the *a priori* level of significance (*P* = 0.01) (**Figure 2**). The mean GWG was 12.0 (2.8) kg, representing a large statistically significant increase (SMD = 1.306, *P* < 0.0005) (**Figure 3**). However, there was no correlation between mean incremental energy intake and GWG (**Figure 4A**, r = 0.321, *P* = 0.11). Only 1 study [36] (18 women, BMI 21.7 (3) kg/m^2) reported a mean increase in energy intake in line with pregnancy guidelines, i.e. 1700 kJ/day (GWG 11.4 (3.7) kg).

When comparing studies from developing (SMD = 0.715, P = 0.156, *n* = 4) and developed countries (SMD = 0.175, P = 0.010, *n* = 22), the change in energy intake did not reach statistical level of significance (P = 0.277, Mood's median Test). Similarly when comparing change in weight in both developed (SMD = 1.310, P < 0.0005, *n* = 22) and developing countries (SMD = 1.297, P < 0.0005, *n* = 4), the difference did not reach statistical significance (P = 1.000, Mood Median Test).

There was no difference in incremental energy intake across BMI groupings, including obese (SMD = 0.083, *P* = 0.611, *n* = 5), underweight (SMD = 0.103, *P* = 0.421, *n* = 1), normal (SMD = 0.314, *P* = 0.033, *n* = 16) and overweight (SMD = 0.378, *P* = 0.019, *n* = 4) groups. In contrast, GWG differed significantly among the BMI groups, with a downward trend in weight gain as BMI increased. The largest effect was seen in the underweight group (SMD = 1.658, *P* < 0.0005, *n* = 1), followed by normal weight (SMD = 1.448, *P* < 0.0005, *n* = 16) and overweight (SMD = 1.245, *P* < 0.0005, *n* = 4). The smallest GWG was seen in the obese women (SMD = 0.0845, P < 0.0005, n = 5), where all interventions were aimed at reducing GWG. Despite this, the inverse relationship between mean BMI and GWG did not reach statistical significance (**Figure 4B**, r = -0.363, P = 0.068).

Regardless of mean BMI, mean weight gain remained within the range of 10 to 16 kg for the majority of studies. Comparing GWG to IOM recommendations, 1 study population classified as underweight did not meet the IOM recommendation of 12.5-18 kg [12] with a mean weight gain of 10.9 kg. Nine of 16 studies with a mean BMI in the normal range met IOM recommendations for GWG of 11.5 to 15.5 kg [12] (IQR 11.3 to 14.8 kg, median 13.1 kg). Two studies exceeded the range, 4 studies fell short (10.2 to 11.4 kg) and 1 study was far below recommendations (6.1 kg). For overweight women, only 1 study met the guidelines of a 6.5 to 11.5 kg gain [12], 1 fell short and the remaining 2 studies had a mean weight gain exceeding recommendations (IQR 7.7 to 14.2 kg, median 12.7 kg). Of the 5 studies in obese populations, 1 study fell within the guidelines of 5.0 to 9.0 kg [12], the other 4 exceeded recommendations with a mean gain of 9.8 to 11.3 kg (IQR 8.2 to 12.1 kg, median 10.6 kg). Comparing study types, RCT showed a lower SMD in energy intake (SMD = 0.081, P = 0.354, n = 9) than observational studies (SMD = 0.361, P = 0.017, n = 17) but the difference was non-significant. SMD for weight gain showed a large effect for both study types, with RCTs showing a lower effect (SMD = 1.090, P < 0.0005, n = 9) than observational studies (SMD = 1.431, P < 0.0005, n = 17).

Only when energy intake was assessed with diet history (SMD = 0.481, P = 0.006, n = 2), an increase in intake was observed. Neither food records (SMD = 0.181, P = 0.015, n = 18) nor 24 hour recalls (SMD = 1.024, P = 0.204, n = 2) were able to demonstrate a change in energy intake. Interestingly, studies using a food diary or photographs (n = 3) revealed a decrease in energy intake from early to late pregnancy (SMD = -0.047, P = 0.452, n = 3) although did not reach statistical significance. When analyzed according to macronutrient distribution (% energy), there was a small but significant increase in carbohydrate intake between early and late pregnancy (SMD = 0.13, P = 0.006), but no significant effect on fat or protein intake.

Risk of Bias of Included Studies

A funnel plot (**Figure 5**) was produced with an almost even distribution of points to the left and right of the solid vertical line in the figure. In addition, Begg and Mazumdar's rank correlation was 0.163 (two-tailed p-value = 0.252) and Egger's regression intercept was 0.528 (two-tailed P-value = 0.826), which suggests that there is no publication bias in our meta-analysis.

COMMENT

To our knowledge, this is the first study to use meta-analysis to explore the relationship between changes in food energy intake in pregnancy and maternal weight gain. In a comprehensive body of literature from developed and developing countries, we found no relationship between the increment in energy intake from early to late pregnancy and the amount of GWG. Indeed, despite a large highly significant increase in body weight (+12.0 kg), there was only a small, non-significant increase in reported energy intake (+475 kJ/day). The findings were similar when the intervention arms of the RCT were removed from the meta-analysis. The average energy intake increment was slightly higher (~650 kJ/day, P = 0.009), but still much lower than the theoretical requirement of 1.4-1.9 MJ/day. Furthermore, weight gain in this sub-group was almost identical to the bigger cohort (+12.1 kg).

Others have reported little or no difference in energy intake between pre-pregnancy/early pregnancy and late pregnancy [47-49]. A recently published longitudinal study by Abeysekera and colleagues [49] also found that energy intake did not differ between any trimester of pregnancy. On the other hand, a review of 9 prospective studies from a previous generation of women (1971-1993) [50] reported a mean increase in energy of 300 kJ/day, comparable to the present analysis, and also well below recommendations for pregnancy [16]. Unlike the present study, however, the rise in energy intake was not investigated in the light of GWG [16,17]. While Streuling et al. [11] conducted a systematic review of the literature, they did not apply meta-analysis to either energy intake or GWG.

It is possible, of course, that underreporting of food intake explains our findings. Higher levels of underreporting are more likely among those with a higher BMI and lower education levels [47,51]. However, underreporting is lower in pregnant women than in the general population, with recorded rates of 11-33% in the first trimester, 16% in the second and 18% in the third [47,51]. Higher rates during the first trimester may be due to inadequate dietary intake as a result of nausea and vomiting that commonly accompanies early gestation rather than underreporting itself [47]. This phenomenon, however, would inflate the difference in energy intake between early and late pregnancy.

We found that studies from developing countries had a higher increment in energy intake than those from developed countries, although the difference was not significant. A potential source of between-study variation is the dietary methodology. Indeed, it is well recognized that Food Frequency Questionnaires (FFQs) usually generate higher energy intake than dietary record estimates[52]. Individuals are also likely to alter food intake during their data collection period[53]. In our meta-analysis, food records were the predominant dietary collection tool when compared to diet history and food diaries, making it impossible to draw conclusions on the extent of under-reporting for each dietary assessment tool.

The lack of correlation between additional energy intake and GWG suggests that factors other than additional food intake may be responsible for the physiological weight gain of pregnancy. Well-designed studies using objective methodology under free-living conditions indicate that women markedly reduce energy expenditure as pregnancy progresses. Energy savings of ~900 kJ/day have been documented [19], with a reduction in physical activity level (PAL) from 1.9 to 1.7 in developing (62), and PAL 1.8 to 1.6 in developed countries [19]. This is achieved by a shift towards less vigorous activities and greater sedentary time [19,54], thereby counterbalancing a higher BMR [55]. With up to 60% of the present generation of pregnant women already inactive prior to conception [54], and greater proportions beginning pregnancy overweight or obese, declining physical activity and increasing sedentary behavior, not higher food intake, may explain the positive energy deposition of pregnancy.

Studies have also shown that metabolic and behavioral adaptations occur during pregnancy at varying levels of pre-pregnancy nutrition. Gambian women display a decreased BMR, and energy sparing adaptations early in pregnancy to allow for weight gain despite severe under-nutrition [50]. Leptin and insulin are important regulators of food intake and energy balance and may influence GWG. Insulin resistance and leptin concentration increase as pregnancy progresses [56,57]. There is a strong positive correlation between BMI and first and third trimester insulin and leptin concentrations [41], with GWG increasing as baseline leptin concentrations rise [57]. Women with a normal pre-pregnancy BMI and elevated plasma leptin concentrations at baseline are predisposed to greater GWG [57].

Although our search strategy revealed almost 2500 potentially relevant studies, the majority report energy intake at only one time point. They are therefore unable to capture the change in energy intake or determine the relationship with weight gain over time. Hence, any single measurement may reflect a high pre-pregnancy energy intake rather than an absolute increase during pregnancy.

This study has strengths and limitations. Strict inclusion/exclusion criteria resulted in two large pregnancy studies being excluded. The Danish Health Cohort [58] (n = 47003) and Nurses' Health Study II [59] (n = 13110) were excluded as dietary data were collected at one time point only. Most studies were observational in nature and therefore susceptible to the effects of bias and confounding, as well as the potential for measurement error and under or over reporting of dietary intake. Effects were minimized by conducting an independent assessment of study quality, stratifying data according to dietary collection method and study type, and using the random-effect model in statistical analysis to assume heterogeneity. In addition, only articles published after 1990 were included as they were deemed more applicable to current context of high prevalence of overweight and obesity at the time of conception.

An important implication of our study is that the current generation of women are unlikely to meet the increased micronutrient requirements that are dictated by a growing fetus. If dietary energy intake is not increased, then iron, calcium, iodine, folic acid and other critical nutrients will be ingested at levels similar to pre-pregnancy [48]. Our findings have important clinical implications for dietary advice for pregnancy, with little or no emphasis on increasing food intake, and more emphasis on higher dietary quality with richer micronutrient composition and recommended supplement use. Strict adherence to current energy guidelines for pregnancy (+1100 kJ/day) could well result in excessive GWG with potentially adverse consequences for maternal and offspring health. These findings call for more case cohort studies to evaluate the effect of a reduction of energy intake on gestational weight gain and pregnancy outcomes.

CONCLUSIONS

Despite a period of uniquely rapid weight gain, women appear to consume only one quarter of the theoretical requirement for additional energy (2000 kJ/day in trimester 3) during pregnancy. Given the high prevalence of obesity and excessive GWG in the current generation of women of reproductive age, dietary guidelines for pregnancy may need to be revised.

Acknowledgements

This research project was undertaken by two students JM and HJ as part of their MNUTRDIET degree with special thanks to TP for her work on statistical analysis and to supervisors JCYL and JBM for their time, guidance and overall contribution in this research project.

Authors' contribution

JCYL and JBM conceptualized the meta-analysis. JM and HJ developed the search strategy under the guidance of JCYL and JCBM. JM and HJ carried out the systematic search, screened and reviewed the articles, and extracted the data from the included studies. JCYL and JBM acted as an adjudicating reviewer when required. TP performed the meta-analysis. All authors were involved in the interpretation of the data. HJ and JM drafted the manuscript. All authors have substantial input into the subsequent edits of the manuscript, and have read and approved the final manuscript.

Conflict of Interest

The authors declare they have no conflict of interest.

Funding

The authors received no financial support for the research or authorship of this article.

REFERENCES

1. Davis E, Olson C. Obesity in Pregnancy. *Primary Care: Clinics in Office Practice.* 2009;36(2):341-356.
2. Chu SY, Kim SY, Bish CL. Prepregnancy obesity prevalence in the United States, 2004-2005. *Maternal and child health journal.* 2009;13(5):614-620.
3. Ovesen P, Rasmussen S, Kesmodel U. Effect of prepregnancy maternal overweight and obesity on pregnancy outcome. *Obstetrics and gynecology.* 2011;118(2 Pt 1):305-312.
4. Guelinckx I, Devlieger R, Beckers K, Vansant G. Maternal obesity: pregnancy complications, gestational weight gain and nutrition. *Obesity reviews : an official journal of the International Association for the Study of Obesity.* 2008;9(2):140-150.
5. Cnattingius S, Bergström R, Lipworth L, et al. Prepregnancy Weight and the Risk of Adverse Pregnancy Outcomes. *The New England journal of medicine.* 1998;338(3):147-152.
6. Persson M, Bonamy A-KE, Cnattingius S, et al. Maternal Obesity and Risk of Preterm Delivery. *JAMA.* 2013;309(22):2362-2370.
7. Stothard KJ, Tennant PWG, Bell R. Maternal Overweight and Obesity and the Risk of Congenital Anomalies: A Systematic Review and Meta-analysis. *JAMA [H.W.Wilson - GS].* 2009;301(6):636.
8. Budge H, Gnanalingham MG, Gardner DS, Mostyn A, Stephenson T, Symonds ME. Maternal nutritional programming of fetal adipose tissue development: long-term consequences for later obesity. *Birth defects research. Part C, Embryo today : reviews.* 2005;75(3):193-199.
9. Callaway LK, Prins JB, Chang AM, McIntyre HD. The prevalence and impact of overweight and obesity in an Australian obstetric population. *The Medical journal of Australia.* 2006;184(2):56.
10. Boney CM, Verma A, Tucker R, Vohr BR. Metabolic Syndrome in Childhood: Association With Birth Weight, Maternal Obesity, and Gestational Diabetes Mellitus. *Pediatrics.* 2005;115(3):e290-e296.
11. Streuling I, Beyerlein A, Rosenfeld E, Schukat B, von Kries R. Weight gain and dietary intake during pregnancy in industrialized countries--a systematic review of observational studies. *Journal of Perinatal Medicine.* 2011;39(2):123-129.
12. Rasmussen KM YA. *Weight Gain During Pregnancy: Reexamining the Guidelines.* 2009. ISBN-13: 978-0-309-13113-1.
13. O'Dwyer V, O'Toole F, Darcy S, Farah N, Kennelly MM, Turner MJ. Maternal obesity and gestational weight gain. *Journal of Obstetrics & Gynaecology.* 2013;33(7):671-674.
14. Rooney BL, Schauberger CW. Excess pregnancy weight gain and long-term obesity: one decade later. *Obstetrics & Gynecology.* 2002;100(2):245-252.
15. Hytten FE, Leitch I. *The physiology of human pregnancy.* Oxford: Blackwell Scientific; 1971.
16. Butte NF, King JC. Energy requirements during pregnancy and lactation. *Public Health Nutrition.* 2005;8(7A):1010-1027.
17. Blumfield ML, Hure AJ, Macdonald-Wicks L, Smith R, Collins CE. Systematic review and meta-analysis of energy and macronutrient intakes during pregnancy in developed countries. *Nutrition reviews.* 2012;70(6):322-336.
18. United Nations U, World Health O, Food, Agriculture Organization of the United N. *Human energy requirements: report of a Joint FAO/WHO/UNU Expert Consultation : Rome, 17-24 October 2001.* Rome: Food and Agricultural Organization of the United Nations;2004. 9251052123; 9789251052129.
19. Löf M, Hälsouniversitetet, Nutrition, Institutionen för klinisk och experimentell m, Linköpings u. Physical activity pattern and activity energy expenditure in healthy pregnant and non-pregnant Swedish women. *European journal of clinical nutrition.* 2011;65(12):1295-1301.
20. Institute of Medicine . Subcommittee on Nutritional S, Weight Gain during P, Institute of Medicine . Subcommittee on Dietary I, Nutrient Supplements during P. *Nutrition during*

pregnancy: part I, weight gain : part II, nutrient supplements. Washington, D.C: National Academy Press; 1990.

21. Spong CY. Defining "term" pregnancy: recommendations from the Defining "Term" Pregnancy Workgroup. *JAMA.* 2013;309(23):2445.
22. Nations U. Statistical Annex - Country Class. 2013.
23. Lof M, Hilakivi-Clarke L, Sandin SS, de Assis S, Yu W, Weiderpass E. Dietary fat intake and gestational weight gain in relation to estradiol and progesterone plasma levels during pregnancy: A longitudinal study in Swedish women. *BMC Women's Health.* 2009;9((Lof M., marie.lof@ki.se; Sandin S.S., sven.sandin@ki.se; Weiderpass E., elisabete.weiderpass.vainio@ki.se) Department of Medical Epidemiology and Biostatistics, Karolinska Institute, SE-171 77 Stockholm, Sweden).
24. Tabrizi FM, Saraswathi G. Maternal nutrient intake and maternal serum micronutrients and their relation to birth weight-A longitudinal study. *International Journal of Collaborative Research on Internal Medicine and Public Health.* 2011;3(8):617-632.
25. Borenstein M. *Introduction to meta-analysis.* Chichester, U.K: John Wiley & Sons; 2009.
26. Cohen J. *Statistical power analysis for the behavioral sciences.* Hillsdale, N.J: L. Erlbaum Associates; 1988.
27. Dietetics AoNa. Evidence analysis manual: steps in the academy evidence analysis process. 2012.
28. Stephens TV, Woo H, Innis SM, Elango R. Healthy pregnant women in Canada are consuming more dietary protein at 16- and 36-week gestation than currently recommended by the Dietary Reference Intakes, primarily from dairy food sources. *Nutrition Research.* 2014((Stephens T.V.; Woo H.; Innis S.M.; Elango R., relango@cfri.ubc.ca) Child and Family Research Institute, BC Children's Hospital, Vancouver, British Columbia, Canada).
29. Talai Rad N, Ritterath C, Siegmund T, et al. Longitudinal analysis of changes in energy intake and macronutrient composition during pregnancy and 6 weeks post-partum. *Archives of Gynecology and Obstetrics.* 2011;283(2):185-190.
30. Piirainen T, Isolauri E, Lagström H, Laitinen K. Impact of dietary counselling on nutrient intake during pregnancy: a prospective cohort study. *British Journal of Nutrition.* 2006;96(6):1095-1104.
31. De Vriese SR, De Henauw S, De Backer G, Dhont M, Christophe AB. Estimation of Dietary Fat Intake of Belgian Pregnant Women. *Annals of Nutrition & Metabolism.* 2001;45(6).
32. Martinez H, Allen LH, Lung'aho M, Chavez A, Pelto GH. Maternal fatness in Mexican women predicts body composition changes in pregnancy and lactation. *Advances in Experimental Medicine & Biology.* 1994;352:99-107.
33. Kubota K, Itoh H, Tasaka M, et al. Changes of maternal dietary intake, bodyweight and fetal growth throughout pregnancy in pregnant Japanese women. *Journal of Obstetrics & Gynaecology Research.* 2013;39(9):1383-1390.
34. Carbone P, Sobreviela M, Jimenez D, Martinez C, De Aguero RG, Pocovi M. Maternal leukocyte metabolism during pregnancy and puerperium, and its relation to fetal growth. *Acta Obstetricia et Gynecologica Scandinavica.* 1992;71(4):266-272.
35. Goodarzi Khoigani M, Paknahad Z, Mardanian F. The relationship between nutrients intake and preeclampsia in pregnant women. *Journal of Research in Medical Sciences.* 2012;17(SUPPL.2):S210-S217.
36. Piers LS, Diggavi SN, Thangam S, Van Raaij JMA, Shetty PS, Hautvast JGAJ. Changes in energy expenditure, anthropometry, and energy intake during the course of pregnancy and lactation in well-nourished Indian women. *American Journal of Clinical Nutrition.* 1995;61(3):501-513.
37. Alberti-Fidanza A. Diet during pregnancy and total antioxidant capacity in maternal and umbilical cord blood. *Journal of Maternal-Fetal and Neonatal Medicine.* 2002;12(1):59-63.

38. Conway R, Reddy S, Davies J. Dietary restraint and weight gain during pregnancy. *European Journal of Clinical Nutrition.* 1999;53(11):849-853.
39. Fung EB, Ritchie LD, Woodhouse LR, Roehl R, King JC. Zinc absorption in women during pregnancy and lactation: a longitudinal study. *The American journal of clinical nutrition.* 1997;66(1):80.
40. Hronek M, Doubkova P, Hrnciarikova D, Zadak Z. Dietary intake of energy and nutrients in relation to resting energy expenditure and anthropometric parameters of Czech pregnant women. *European Journal of Nutrition.* 2013;52(1):117-125.
41. Jansson N, Nilsfelt A, Gellerstedt M, et al. Maternal hormones linking maternal body mass index and dietary intake to birth weight. *American Journal of Clinical Nutrition.* 2008;87(6):1743-1749.
42. Kopp-Hoolihan LE, van Loan MD, Wong WW, King JC. Longitudinal assessment of energy balance in well-nourished, pregnant women... including commentary by Pitkin RM [corrected] [published erratum appears in AM J CLIN NUTR 2000 Jan; 71(1): 157]. *American Journal of Clinical Nutrition.* 1999;69(4):697.
43. Guelinckx I, Devlieger R, Mullie P, Vansant G. Effect of lifestyle intervention on dietary habits, physical activity, and gestational weight gain in obese pregnant women: A randomized controlled trial. *American Journal of Clinical Nutrition.* 2010;91(2):373-380.
44. Korpi-Hyövälti E, Schwab U, Laaksonen DE, Linjama H, Heinonen S, Niskanen L. Effect of intensive counselling on the quality of dietary fats in pregnant women at high risk of gestational diabetes mellitus. *British Journal of Nutrition.* 2012;108(5):910-917.
45. Moses RG, Casey SA, Quinn EG, et al. Pregnancy and Glycemic Index Outcomes study: Effects of low glycemic index compared with conventional dietary advice on selected pregnancy outcomes. *American journal of clinical nutrition.* 2014(3):517-523. http://onlinelibrary.wiley.com/o/cochrane/clcentral/articles/961/CN-00981961/frame.html.
46. Wolff S, Legarth J, Vangsgaard K, Toubro S, Astrup A. A randomized trial of the effects of dietary counseling on gestational weight gain and glucose metabolism in obese pregnant women. *International Journal of Obesity.* 2008;32(3):495-501.
47. Winkvist A, Persson V, Hartini TNS. Underreporting of energy intake is less common among pregnant women in Indonesia. *Public Health Nutrition.* 2002;5(4):523-529.
48. dos Santos Q, Sichieri R, Marchioni DML, Verly Junior E. Brazilian pregnant and lactating women do not change their food intake to meet nutritional goals. *BMC pregnancy and childbirth.* 2014;14(1):186.
49. Abeysekera MV, Morris JA, Davis GK, O'Sullivan AJ. Alterations in energy homeostasis to favour adipose tissue gain: A longitudinal study in healthy pregnant women. *Australian and New Zealand Journal of Obstetrics and Gynaecology.* 2015.
50. Prentice AM, Poppitt SD, Goldberg GR, Prentice A. Adaptive strategies regulating energy balance in human pregnancy. *Human reproduction update.* 1995;1(2):149-161.
51. McGowan CA, McAuliffe FM. Maternal nutrient intakes and levels of energy underreporting during early pregnancy. *European journal of clinical nutrition.* 2012;66(8):906-913.
52. Erkkola M, Karppinen M, Javanainen J, Räsänen L, Knip M, Virtanen SM. Validity and reproducibility of a food frequency questionnaire for pregnant Finnish women. *American Journal of Epidemiology.* 2001;154(5):466-476.
53. Macdiarmid J, Blundell J. Assessing dietary intake: Who, what and why of under-reporting. *Nutrition Research Reviews.* 1998;11(2):231-253.
54. Poudevigne MS, Oconnor PJ. A Review of Physical Activity Patterns in Pregnant Women and Their Relationship to Psychological Health. Vol 36. Cham: Adis International; 2006:19-19.
55. Dufour DL, Reina JC, Spurr GB. Energy intake and expenditure of free-living, lactating Colombian women in an urban setting. *European Journal of Clinical Nutrition.* 2002;56(3):205-213.

56. Lain KY, Catalano PM. Metabolic Changes in Pregnancy. *Clinical obstetrics and gynecology.* 2007;50(4):938-948.
57. Stein TP, Scholl TO, Schluter MD, Schroeder CM. Plasma leptin influences gestational weight gain and postpartum weight retention. *American Journal of Clinical Nutrition.* 1998;68(6):1236-1240.
58. Knudsen VK, Heitmann BL, Halldorsson TI, Sorensen TIA, Olsen SF. Maternal dietary glycaemic load during pregnancy and gestational weight gain, birth weight and postpartum weight retention: A study within the Danish National Birth Cohort. *British Journal of Nutrition.* 2013;109(8):1471-1478.
59. Zhang C, Liu S, Solomon CG, Hu FB. Dietary fiber intake, dietary glycemic load, and the risk for gestational diabetes mellitus. *Diabetes Care.* 2006;29(10):2223-2230.

Table 1. Assessing the risk of bias in individual studies using the Quality Criteria Checklist obtained from the American Dietetic Association Evidence Analysis Manual.

	Was the research question clearly stated?	Was the selection of study subjects free from bias?	Were study groups comparable?	Was method of handling withdrawals described?	Was blinding used to prevent introduction of bias?	Were intervention procedure and comparison(s) described in detail? Where intervening factors described?	Were outcomes clearly defined and the measurements valid and reliable?	Was the statistical analysis appropriate for the study design and type of outcome indicators?	Are conclusions supported by results with biases and limitations taken into consideration?	Is bias due to study's funding or sponsorship unlikely?	Overall Quality Rating
Alberti-Fidanza et al.[37]	√	(-)	(-)	√	(x)	√	√	√	√	√	Neutral
Carbone et al.[34]	√	√	√	√	(-)	(-)	√	(-)	(-)	√	Neutral
Conway et al.[38]	√	√	√	√	(-)	(-)	√	√	√	(-)	Neutral
De Vriese[31]	√	√	√	(-)	(x)	(-)	√	√	√	√	Neutral
Fung et al.[39]	√	√	√	√	(-)	√	√	√	√	√	Positive
Goodarzi Khoigani et al.[35]	√	√	√	(-)	(-)	(-)	√	(-)	√	√	Neutral
Guelinckx et al.[43]	√	√	√	√	(-)	(-)	√	√	√	√	Neutral
Hronek et al.[40]	√	√	(-)	(x)	(x)	(-)	√	√	√	√	Neutral
Jansson et al.[41]	√	√	√	√	(x)	(-)	√	√	√	√	Neutral
Kopp Hoolihan et al.[42]	√	(-)	√	√	(x)	(-)	√	√	(-)	√	Neutral
Korpi Hyovalti et al.[44]	√	√	√	√	(x)	(-)	√	√	√	√	Neutral
Kubota et al.[33]	√	√	√	(x)	(-)	(-)	(-)	(-)	√	√	Neutral
Lof et al.[23]	√	(-)	√	√	(x)	(-)	√	(-)	√	√	Neutral

	Was the research question clearly stated?	Was the selection of study subjects free from bias?	Were study groups comparable?	Was method of handling withdrawals described?	Was blinding used to prevent introduction of bias?	Were intervention procedure and comparison(s) described in detail? Where intervening factors described?	Were outcomes clearly defined and the measurements valid and reliable?	Was the statistical analysis appropriate for the study design and type of outcome indicators?	Are conclusions supported by results with biases and limitations taken into consideration?	Is bias due to study's funding or sponsorship unlikely?	Overall Quality Rating
Martinez et al.[32]	√	(-)	(x)	(-)	(x)	(-)	(-)	(x)	(-)	√	Neutral
Moses et al.[45]	√	√	(-)	√	(x)	(-)	√	√	√	√	Neutral
Piers et al.[36]	√	(-)	√	(-)	(x)	(-)	√	√	(-)	√	Neutral
Tabrizi et al.[24]	√	√	√	(-)	(x)	(-)	(-)	(-)	√	√	Neutral
Wolff et al.[46]	√	√	√	√	√	√	√	√	√	√	Positive

Key: √ = yes, (x) = no, (-) = unclear

Table 2. Study characteristics; values are reported as mean ± standard deviation

Observational studies							
Source	**Aim**	**Study population**	**Dietary assessment method**	**Inclusion/ exclusion criteria**	**Conclusion**	**Limitations**	**Quality rating & retention**
Alberti-Fidanza et al.[37], 2002	To examine longitudinally the total antioxidant capacity (ToAC) of women from early pregnancy to delivery and of their newborns, and relate the results to the dietary intake of the same women during pregnancy.	Italy, developed *n* = 12 BMI 22.6 (5.5) kg/m^2 Age 31.1 (4.2) years Parity 1.8 (0.9) nil smokers	Collected by qualified and experienced dietitians using the diet history method during the 1st, 2nd and 3rd trimesters.	Not stated	It is important to monitor ToAC values during the entire period of pregnancy and we suggest large intakes of fruit and vegetables and, if necessary, antioxidant vitamin and pro-vitamin supplements. Data regarding the antioxidant status of mothers and newborns, particularly if preterm, may offer valuable information for increasing the chance that pregnancies proceed successfully to term and achieve physiological deliveries.	Small sample size; possible selection bias as inclusion criteria not reported; factors such as pollution, ionizing radiation, and smoking habits may interfere with antioxidant status.	Neutral Not reported

Observational studies							
Source	**Aim**	**Study population**	**Dietary assessment method**	**Inclusion/ exclusion criteria**	**Conclusion**	**Limitations**	**Quality rating & retention**
Carbone et al.[34], 1992	Present patterns of leukocyte energy metabolism during normal pregnancy and puerperium and its possible relationship to fetal growth and maternal nutrient intake.	Spain, developed *n* = 33 BMI 22.7 (2.2) kg/m^2 Age 28 (3.6) years Parity of 1 *n* = 18, 2,3,4 *n* = 15	3-day weight food record including 1 holiday completed at 11, 19 and 35 weeks gestation.	Gestational age less than 12 weeks, normal menstrual cycles before conception, no personal or family history of metabolic, vascular and/or genetic disorders, no apparent disease present at the time of visit and pregnancy classification as low risk.	There was a correlation between protein/DNA ratio and head circumference at 36 weeks of gestation. Findings may suggest a relationship between the metabolism of maternal leukocytes and fetal development in utero.	Small sample size; selection bias due to 66% retention rate.	Neutral 66%

Observational studies							
Source	**Aim**	**Study population**	**Dietary assessment method**	**Inclusion/ exclusion criteria**	**Conclusion**	**Limitations**	**Quality rating & retention**
Conway et al.[38], 1999	To explore the relationship between dietary restraint and appropriateness of weight gain during pregnancy using AIM criteria and to assess dietary intake during pregnancy in relation to dietary restraint.	England, developed **Restrained:** *n* = 32 BMI 22 (2.4) kg/m^2 Age 31.2 (4.6) years Parity of 1 *n* = 28, 2 *n* = 4 **Unrestrained:** *n* = 30 BMI 20.7 (1.96) kg/m^2 Age 30.6 (3.6) years Parity of 1 *n* = 26, 2 *n* = 4	7-day weighed food record at 12 and 30 weeks gestation	Caucasian women, expecting their first or second singleton baby, over 18yrs of age, and free from any medical condition which might affect nutrition or fetal outcomes.	Providing pregnant women with more guidance about appropriate weight gains may be beneficial. As cessation of smoking during pregnancy was associated with large weight gains it would be prudent to accompany any advice about stopping smoking during pregnancy with advice about eating and weight gain.	Small sample size; not a representative sample, non-responders had a higher BMI than responders.	Neutral 81%

Observational studies							
Source	**Aim**	**Study population**	**Dietary assessment method**	**Inclusion/ exclusion criteria**	**Conclusion**	**Limitations**	**Quality rating & retention**
De Vriese et al.[31], 2001	To determine the relative validity and usefulness of a Dutch food frequency questionnaire (FFQ) adapted to the Belgian diet by comparing dietary fat intake data collected by this FFQ with the 7d food record in pregnant Belgian women during the 1st and 3rd trimesters.	Belgium, developed *n* = 26 BMI 22 (17.6-29.3) kg/m^2 Age 30 (25-37) years All pregnant women were nulliparous.	7-day estimated food record (EFR) during the 1st (median 15 weeks) and 3rd (median 35 weeks) trimesters. A FFQ containing 180 of the most common fat-containing foods was conducted at the same timepoints. Data recorded was based on the EFR.	First pregnancy, diastolic blood pressure below 90mm Hg, not diabetic, no proteinuria and not suffering from renal or cardiovascular disease.	The FFQ in conjunction with the individual fatty acid composition database of Belgian foods is an adequate method to reasonably rank subjects according to their dietary fat intake.	Small sample size; food composition database used to analyze the 7d EFR lacks a lot of data concerning the linoleic acid content of different foods.	Neutral 78%

Observational studies							
Source	**Aim**	**Study population**	**Dietary assessment method**	**Inclusion/ exclusion criteria**	**Conclusion**	**Limitations**	**Quality rating & retention**
Fung et al.[39], 1997	To determine whether fractional absorption of a stable isotope of zinc from a standardized meal is altered in well-nourished women followed from before conception through lactation and, determine whether the change in fractional zinc absorption (ZFA) is related to indicators of maternal zinc status.	USA, developed *n* = 13 BMI 22.3 (2.9) kg/m^2 Age 30 (2.9) years Parity of 1 *n* = 10, 2 *n* = 3	3-day weighed food record, non-consecutive days, two weekdays and one weekend at 8-10 weeks, 24-26 weeks and 34-36 weeks gestation.	Aged 22-40yrs, body mass index of 19-26 kg/m^2, non-smoking, non-diabetic, non-vegetarian, no drug and alcohol use, and no previous obstetric or gynecological complications.	Well-nourished women met the additional need for zinc during pregnancy by increasing zinc intake and by a 30% increase in zinc absorption that was not significant. The increase in dietary zinc was due largely to an increase in intake of dairy foods. FZA increased 75% early in the lactation period, presumable as an adaptation to the lactation process. These data indicate that mechanisms regulating zinc homeostasis differ between pregnancy and lactation.	Small sample size	Positive 87%

Observational studies							
Source	**Aim**	**Study population**	**Dietary assessment method**	**Inclusion/ exclusion criteria**	**Conclusion**	**Limitations**	**Quality rating & retention**
Hronek et al.[40], 2013	To evaluate the dietary intake of energy and nutrients (DIEN) of Czech pregnant women and compare it with recommended daily allowances (RDA).	Czechoslovakia, developed Participants were randomly recruited from both rural and city regions. *n* = 152 BMI 21.1 (3.6) kg/m^2 Age 28.9 (3.6) years	7-day food record on consecutive days using scales and household measures at 0-20 weeks, 21-29 weeks, 30-36 weeks and 37-39 weeks gestation.	Nonusers of chronic medication, non-smokers and non-abusers of alcohol or drugs and had parity ≤2. Subjects were euthyroid, normoglyceamic and not anemic.	Lower intake of energy and intakes of some nutrients relative to the corresponding RDA during pregnancy. Evaluated DIEN corresponded with body size variables. Modification of food intake or alternatively supplementation is recommended, for folic acid, iron, vitamin D, zinc, iodine and fiber.	Possible selection bias as retention rate not reported; to prevent distortion of the data, intake of supplements was not included in the evaluation, due to irregular intake; deficiencies were not evaluated; only health women with pre-pregnancy BMI in the range of 17.5-24.7 were recruited.	Neutral Retention not reported

Observational studies							
Source	**Aim**	**Study population**	**Dietary assessment method**	**Inclusion/ exclusion criteria**	**Conclusion**	**Limitations**	**Quality rating & retention**
Jansson et al.[41], 2008	To identify hormonal factors that can explain the link between early pregnancy BMI, maternal dietary intake, and birth weight.	Sweden, developing *n* = 49 BMI 25.5 (6.9) kg/m^2 Age 30 (4.5) years	Diet history covering dietary intake over a 24hr period, collected by a registered dietitian at 8-12 weeks and 32-35 weeks gestation.	Inclusion criteria: Scandinavian heritage, healthy and ≥20 years old. Exclusion criteria: smoking, vegetarianism, assisted reproduction, concurrent disease such as eating disorder or diabetes, development of pregnancy complications such as gestational diabetes, preeclampsia, or intrauterine growth restriction.	High first trimester maternal serum resistin and low third trimester IGFBP-1 were correlated with increased birth weight. We propose that low serum concentrations of IGFBP-1 represent a link between high BMI and increased fetal growth by increasing bioavailability of IGF-1, regulating placental nutrient transport.	Small sample size decreased the ability to detect biologically relevant differences.	Neutral 88%

Observational studies							
Source	**Aim**	**Study population**	**Dietary assessment method**	**Inclusion/ exclusion criteria**	**Conclusion**	**Limitations**	**Quality rating & retention**
Khoigani et al.[35], 2012	To assess the association between preeclampsia risk and the intake of 40 macro and micro nutrients during the first, second and third trimesters based on demographic and reproductive characteristics and physical activity of pregnant women.	Iran, developing *n* = 620 (t_1, *n* = 584; t_2, *n* = 510) BMI 23.5 (3.9) kg/m^2 Age 25.6 (4.4) years Parity 1.58 (0.76)	48-hour dietary recall completed at 11-15 weeks, 26 weeks and 34-37 weeks gestation. Interviewers were trained.	Pregnant women who did not have conditions such as factors causing preeclampsia, preterm delivery, low birth weight and factors which may affect pregnancy outcomes such as smoking, drug addiction, digestive and metabolic disease, hemoglobinopathies, eating disorders, allergies, mental diseases and malignancy.	Mean value of saturated fat in the first trimester in subjects who experienced preeclampsia later in pregnancy was higher than in other pregnant women. Intakes of manganese, vitamin C, vitamin E, fiber and carbohydrate during the third trimester were significantly less among pregnant women who developed preeclampsia. No significant associations between other micro and macro nutrients and preeclampsia risk.	Reasons for withdrawal not reported; data was not collected for all subjects at each timepoint, and reasons for this not reported.	Neutral 89%

Observational studies							
Source	**Aim**	**Study population**	**Dietary assessment method**	**Inclusion/ exclusion criteria**	**Conclusion**	**Limitations**	**Quality rating & retention**
Kopp-Hoolihan et al.[42], 1999	To assess how well-nourished women meet the energy demands of pregnancy and to identify factors that predict an individual's metabolic response.	USA, developed *n* = 10 BMI 23.1 (2.1) kg/m^2 Age 29.1 (5) years	3 day weighed food record completed before pregnancy and at 8-10, 24-26, 34-36 weeks gestation and 4-6 weeks post- partum.	Healthy non-smoking women.	Well-nourished women use different ways to meet the energy demands of pregnancy, including reduction in diet induced thermogenesis, increased energy intake, deposition of less fat mass than predicted.	Small sample size; subjects were new to WFR food collection method at t_1, it would have been prudent to ask the subjects to repeat measurements to verify intake.	Neutral 100%

Observational studies							
Source	**Aim**	**Study population**	**Dietary assessment method**	**Inclusion/ exclusion criteria**	**Conclusion**	**Limitations**	**Quality rating & retention**
Kubota et al.[33], 2013	To investigate the associations among changes in dietary intake, maternal bodyweight and fetal growth during pregnancy.	Japan, developed **Underweight** *n* = 32 BMI 17.5 (0.1) kg/m^2 Age 29.7 (5.2) years **Normal** *n* = 94 BMI 21 (1.8) kg/m^2 Age 30.8 (5.1) years **Overweight** *n* = 9 Age 28.6 (3.6) years BMI 33.4 (6.5) kg/m^2	Digital images taken before and after meals on 3 consecutive days at 14-16, 25-27 and 32-34 weeks gestation; a dietitian reviewed photos and recorded intake; validation of method not reported.	Singleton pregnant Japanese women were included; those which had suffered from obstetrical complications such as premature delivery, gestational diabetes, and pre-eclampsia or did not submit digital images were excluded.	Dietary intake was similar throughout pregnancy and did not correlate with fetal growth, despite Japanese national recommendations advising extra energy intake.	Possible selection bias due to low retention rate; no differentiation is made between participants excluded due to complications and those who withdrew from the study; characteristics of withdrawals not described; dietary collection method not validated.	Neutral 55%

Observational studies							
Source	**Aim**	**Study population**	**Dietary assessment method**	**Inclusion/ exclusion criteria**	**Conclusion**	**Limitations**	**Quality rating & retention**
Lof et al.[23], 2009	Investigate whether intakes of total dietary fat, types of fat and weight gain are associated with estradiol and progesterone levels in plasma during pregnancy.	Sweden, developed *n* = 226 BMI 22.9 (3) kg/m^2 Age 32 (4) years	3 day weight food record on consecutive days including one weekend at 12, 25 and 33 weeks gestation. Calculations conducted by a nutritionist.	Women with multi-fetal pregnancies, missing data at baseline questionnaire or for measurements of either body weight or dietary intake were excluded.	No association found between gestational weight gain, maternal dietary fat intake (total or subtypes) and plasma estradiol levels. Progesterone levels correlated with weight gain in pregnancy.	Findings are only relevant to the Caucasian population; dietary intake was self-reported thus misclassifications of dietary intake cannot be excluded.	Neutral 78%
Martinez et al.[32], 1994	To determine how gestational weight gain varies according to BMI in a developing nation, Mexico.	Mexico, developing *n* = 36 BMI 23.5 (2.6) kg/m^2 Age 31 (5.4) years	Diet history collected by trained interviewers twice per month and reported as mean first and third trimester values.	Women with an 18 month old or schooler 7-8 years in the Solis Valley, who became pregnant at the time of initial recruitment provided that they were no more than 5 months pregnant.	In this sample of women, the relationship between BMI at conception, weight gain and pregnancy outcome was similar to that of women in United States. Lower maternal BMI predicted smaller birth weight and size through at least 6 months of life.	Small sample size; large standard deviation in data may reflect the small sample size; withdrawals not reported	Neutral 86%

Observational studies							
Source	**Aim**	**Study population**	**Dietary assessment method**	**Inclusion/ exclusion criteria**	**Conclusion**	**Limitations**	**Quality rating & retention**
Piers et al.[36], 1995	To determine changes in maternal energy metabolism during pregnancy and lactation by comparing a group of well-nourished pregnant and lactating Indian women at 12, 24, and 34 wk. gestation and at 12 and 24 wk. postpartum with a non-pregnant, non-lactating control group.	India, developing *n* = 18 BMI 21.7 (2.4) kg/m^2 Age 29.6 (5.2) years	5 day estimated food record using household measures of known volume at 12, 24, and 34 weeks gestation and 12 and 24 weeks post-partum; participants were trained to use the measure by a dietitian who also checked all records.	Pregnant subjects of good health, were non-smokers, had no appetite affected by morning sickness before the initial metabolic measurement at 12 weeks gestation.	BMR is significantly higher during pregnancy compared with non-pregnant, non-lactating data, and remains high even when differences in body weight are accounted for. Well-nourished Indian women have weight and fat gains similar to those of well-nourished Western women. Birth weights of infants born appeared to be lower. Energy cost of pregnancy estimated to be 303 MJ, close to the 335 MJ estimated by FAOIWHO/UNU.	Small sample size; withdrawals not discussed; methods used for the estimation of energy intake were not as precise as the weighed-intake, but it was less cumbersome; the possibility of a systematic underestimation of energy intake in studies reporting low increments in energy intake during pregnancy cannot be ruled out.	Neutral 82%

Observational studies							
Source	**Aim**	**Study population**	**Dietary assessment method**	**Inclusion/ exclusion criteria**	**Conclusion**	**Limitations**	**Quality rating & retention**
Tabrizi et al.[24], 2011	To assess the relationship between energy, protein and mineral intake of pregnant women and birth weight of their neonates.	Iran, developing *n* = 450 BMI 23.9 (3.8) kg/m^2 Age 26.1 (5.8) years	24 hour Recall collected at the end of the 1^{st}, 2^{nd} and 3^{rd} trimesters. Qualification/ training of interviewer not reported	Women of 16 to 40 years who continuously visited health care centers during the three trimesters in Khoy city	Maternal energy, protein, calcium, iron and zinc intake along with higher maternal serum calcium iron and zinc influenced birth weight of neonates.	Withdrawals not reported; actual consumption of supplements was not monitored.	Neutral Not reported

Randomized controlled trials							
Source	**Aim**	**Study population and intervention**	**Dietary assessment method**	**Inclusion/ exclusion criteria**	**Conclusion**	**Limitations**	**Quality rating & retention**

Randomized controlled trials							
Source	**Aim**	**Study population and intervention**	**Dietary assessment method**	**Inclusion/ exclusion criteria**	**Conclusion**	**Limitations**	**Quality rating & retention**
Guelinckx et al.[43], 2010	Study which degree of intervention can improve dietary habits according to the National Diet Recommendations, increase physical activity level in obese pregnant women, and control gestational weight gain.	Belgium, developed; randomly assigned using block randomization. **Control** (routine): *n* =43 BMI 33.5 (3.9) kg/m^2 Age 29.4 (4.4) yrs. Parity of 1 *n* = 17 **Passive** (nutrition and PA brochure): *n* = 37 BMI 33.4 (3.1) kg/m^2 Age 28.7 (4) yrs. Parity of 1 *n* = 15 **Active** (brochure + group dietary counselling): *n* = 42 BMI 34.1 (4.5) kg/m^2 Age 28 (3.6) yrs. Parity of 1 *n* = 20	7-day food records including both weighed and household measures during each trimester of pregnancy. Records were checked by a nutritionist.	White women attending the prenatal clinic before 15wks gestation. Exclusion criteria: pre-existing diabetes or developing gestational diabetes, multiple pregnancy, premature labor (<37 wks. gestation), primary needs for nutritional advice in case of metabolic disorder, kidney problems, Crohn disease, allergic conditions, and inadequate knowledge of the Dutch language, because this language was used for both the brochure and group discussions.	A lifestyle intervention based on a brochure alone or group sessions combined with individual advice can improve dietary habits throughout pregnancy in obese women. Even in the absence of medical or obstetric complications, maintaining or increasing PA during pregnancy is difficult. To obtain a significant decrease in GWG, an individually designed caloric intake restriction based on energy expenditure data should be included.	Patients in the control group were aware of being included in a study aiming at promoting a healthy lifestyle and reducing gestational weight gain may have influenced dietary records resulting in underestimation of the intervention effect. Nutritional data was incomplete for 27 participants (14%) who were excluded from analysis.	Neutral Control: 66% Passive: 57% Active: 65%

Randomized controlled trials							
Source	**Aim**	**Study population and intervention**	**Dietary assessment method**	**Inclusion/ exclusion criteria**	**Conclusion**	**Limitations**	**Quality rating & retention**
Korpi-Hyovalti et al.[44], 2012	To evaluate the effect of intensive dietary therapy on quality of diet, weight gain and birth weight in women at high risk of gestational diabetes mellitus.	Finland, developed; randomized into group 1 or 2 using computed randomization **Close follow up** (general information on diet and PA) *n* = 27 BMI 25.5 (3.4) kg/m^2 **Lifestyle intervention** (individualized nutrition advice) *n* = 27 BMI 27.3 (6) kg/m^2	4 day weighed food record on consecutive days including one weekend completed at 8-12, 26-28 and 36-40 weeks gestation. Records checked by a nutritionist A three-factor eating questionnaire was also used at the 1st and 3rd trimester.	Women with one or more risk factors for gestational diabetes, venous plasma glucose concentration after 12h overnight fasting was 4.8-5.5 mmol/l and the 2h oral glucose tolerance test plasma glucose <7.8 mmol/l were recruited. Women diagnosed with GDM at 8-12 wks. gestation were excluded.	There were no clear differences in saturated fat and fiber intake, however polyunsaturated fat did increase in the lifestyle intervention group. Intensive weight gain education led to a somewhat lower weight gain during pregnancy, and higher birth weights of the infants in lifestyle intervention but no differences in macrosomia when compared to the close follow up group.	Small sample size; the Three Factor Eating Questionnaire which was used to measure three dimensions of eating behavior (cognitive restraint of eating, disinhibition and hunger), however its benefit was limited in the present study because all women received informative education regardless of the results of the questionnaire.	Neutral Lifestyle intervention: 70% Close follow up: 67%

Randomized controlled trials							
Source	**Aim**	**Study population and intervention**	**Dietary assessment method**	**Inclusion/ exclusion criteria**	**Conclusion**	**Limitations**	**Quality rating & retention**
Moses et al. [45], 2014	To determine whether offering low glycemic index (LGI) dietary advice at the first antenatal visit would result in a lower fetal birth weight, birth percentile, and ponderal index (PI) than providing healthy eating (HE) advice	Australia, developed randomly assigned using computer-generated random numbers 1 or 2 **Healthy Eating** (counselled to follow a healthy diet based on the AGHE[4]) *n* = 280 BMI 24.7 (5) kg/m^2 Age 29.9 (5) yrs. **Low Glycemic Index** (individualized nutrition advice on a LGI diet) *n* = 296 BMI 24.3 (5.2) kg/m^2 Age 29.9 (5.2) yrs.	3 day estimated food record using household measures at 16 and 36 weeks gestation; records reviewed by a dietitian.	Enrolment at < 20 wk. of gestation with a singleton pregnancy, at least 18 years old, ability to read and understand English language, and ability to comply with visit schedules. Subjects excluded if they had: diabetes or previous gestational diabetes, special dietary needs, the presence of medical conditions that could compromise their metabolic status or the use of medications that were likely to influence body weight.	A low intensity dietary intervention with a LGI compared with HE diet in pregnancy did not result in significant differences in birth weight, fetal percentile of PI.	Study personnel not blinded to the dietary assignment; physical activity was not controlled or measured; the study lacked a control group that followed standard pre-natal protocol.	Neutral Healthy eating: 83% Low GI: 84%

Randomized controlled trials							
Source	**Aim**	**Study population and intervention**	**Dietary assessment method**	**Inclusion/ exclusion criteria**	**Conclusion**	**Limitations**	**Quality rating & retention**
Wolff et al.[46], 2008	To determine whether a 10 hour dietary consultations restricts weight gain in obese women and whether this restriction impacts on pregnancy-induced changes in glucose metabolism.	Denmark, developed; Randomized into group 1 or 2 using computed randomization. **Control** (general information on diet and PA) *n* = 27 BMI 25.5 (3.4) kg/m^2 Age 30 (5) years **Intervention** (10 x 1 hour consultations) *n* = 27 BMI 27.3 (6) kg/m^2 Age 28 (4) years	7 day weighed food record at inclusion (15 ± 3 wks.), 27 and 36 weeks gestation.	Pregnant obese women (BMI >30) in their early pregnancy were recruited. Exclusion criteria included: smoking, <18 year old or >45 year old, multiple pregnancy, or medical conditions which impact fetal growth.	Restriction of gestational weight gain in obese women is achievable and reduces the deterioration in glucose metabolism.	Small sample size; Limited generalizability of results due to the scientific settings of the trial with time consuming extra ultra sound scans and blood samples that may have increased the number of drop outs; unrestricted control group knew they were participating in a maternal weight restriction study, which could have influenced gestational weight gain.	Positive 76%

FIGURE LEGENDS

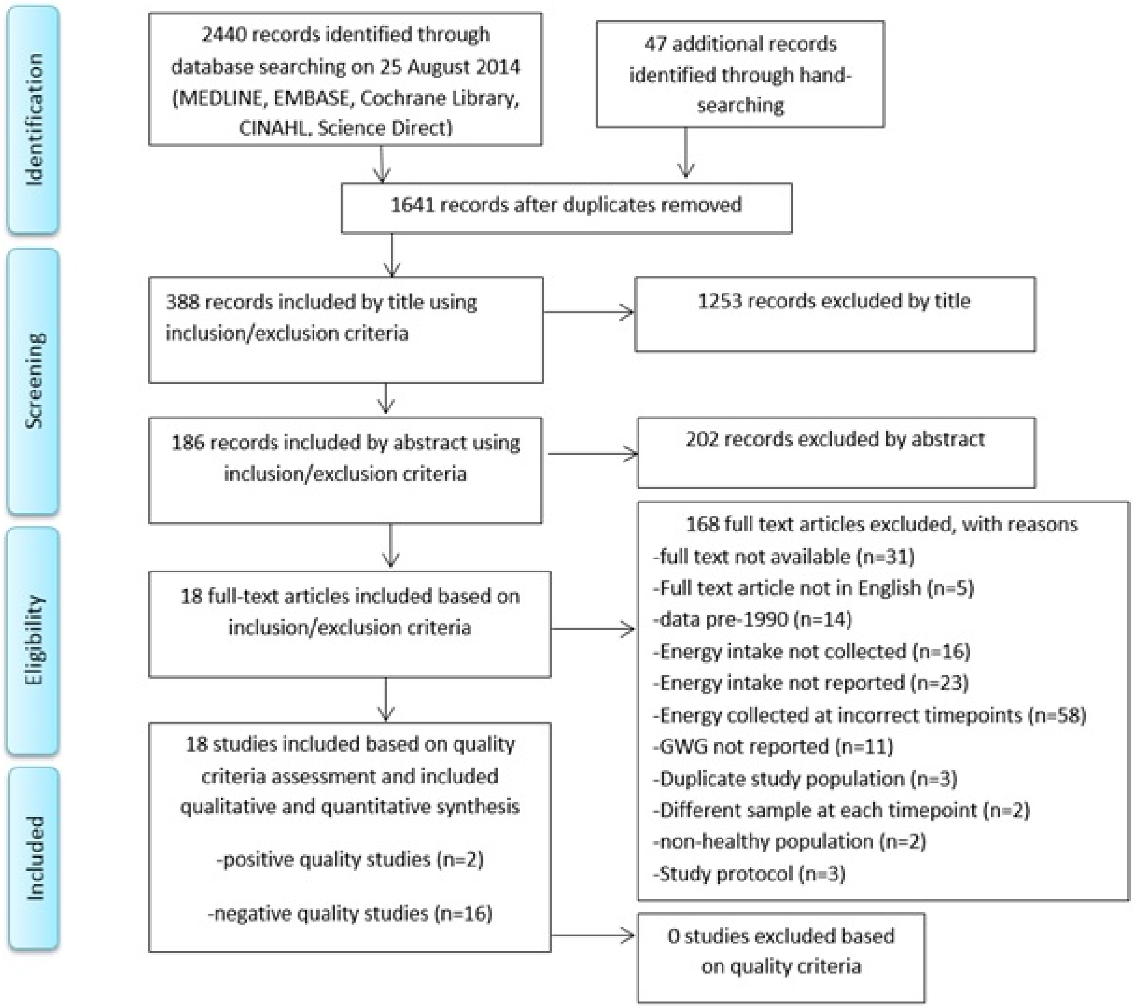

Figure 1 The screening and selection process.

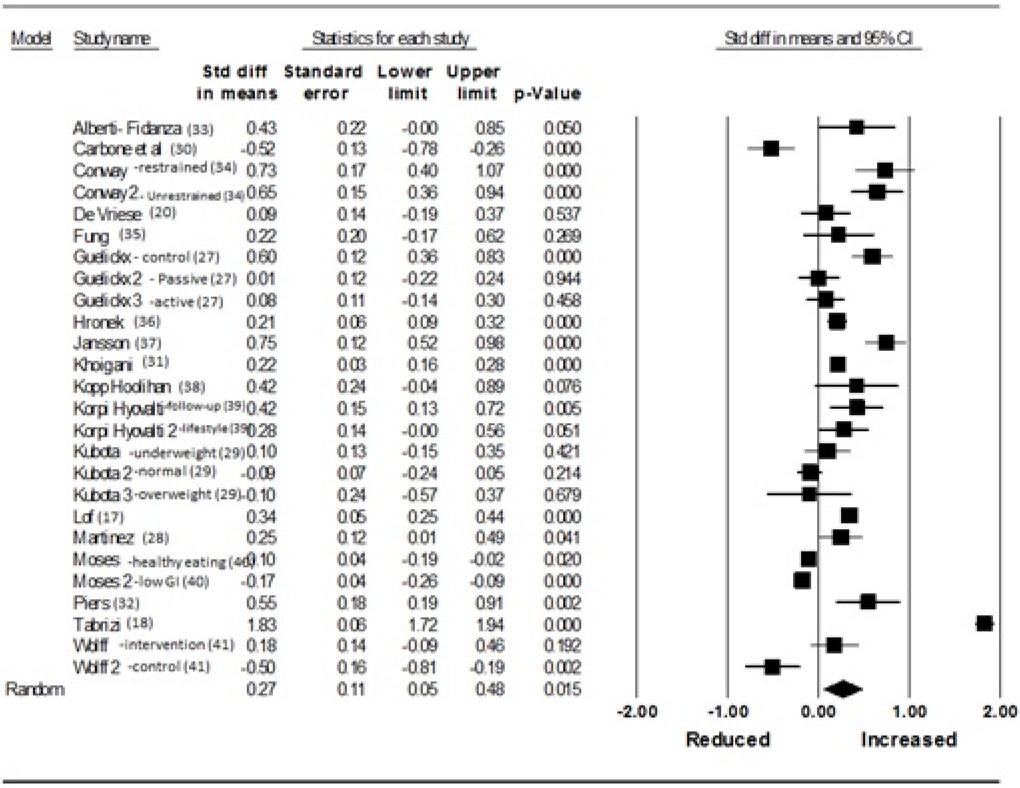

Figure 2 Meta-analysis of the standardized mean difference in energy intake between early and late pregnancy. Overall effect shows a small increase in energy intake which is not significant. Data are expressed as standardized mean difference, using r = 0.74 from Spearman's correlation coefficient with random effects. Study names with an additional numerical value represent a different population group within the study, e.g. control and intervention groups in a randomized controlled trial.

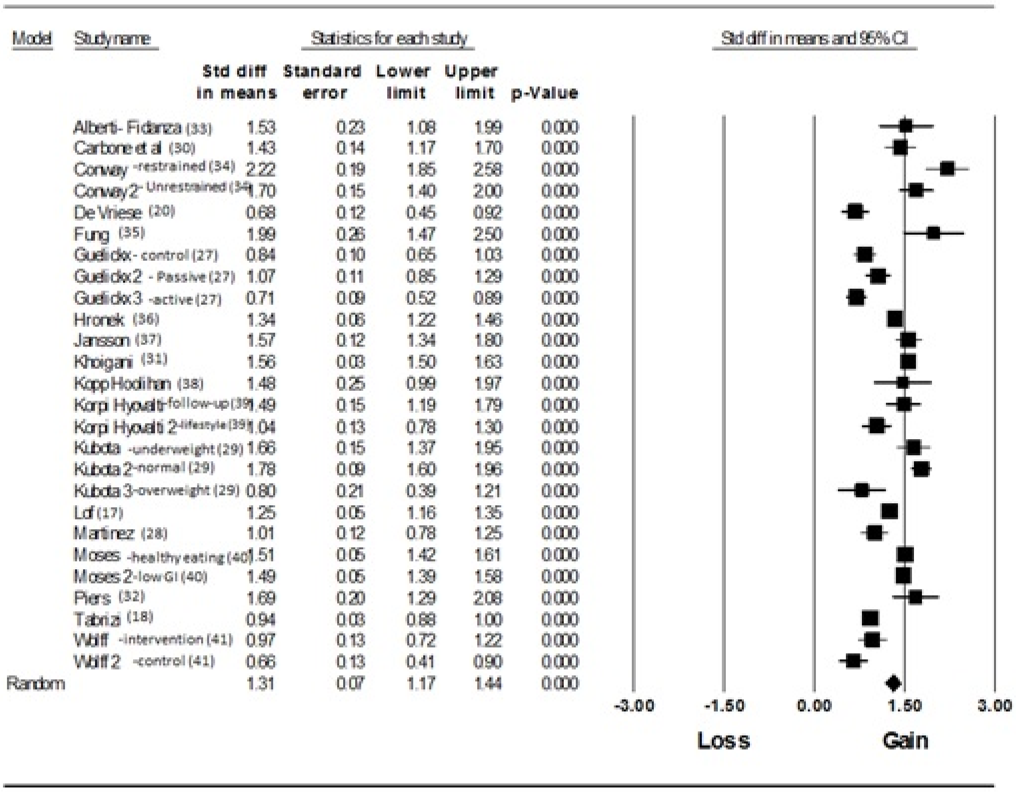

Figure 3 Meta-analysis of the standardized mean difference in gestational weight gain throughout pregnancy. Overall effect shows a significant increase in maternal weight. Data are expressed as standardized mean difference, using r = 0.85 from Spearman’s correlation coefficient with random effects. Study names with an additional numerical value represent a different population group within the study, for example control and intervention groups in a randomized controlled trial.

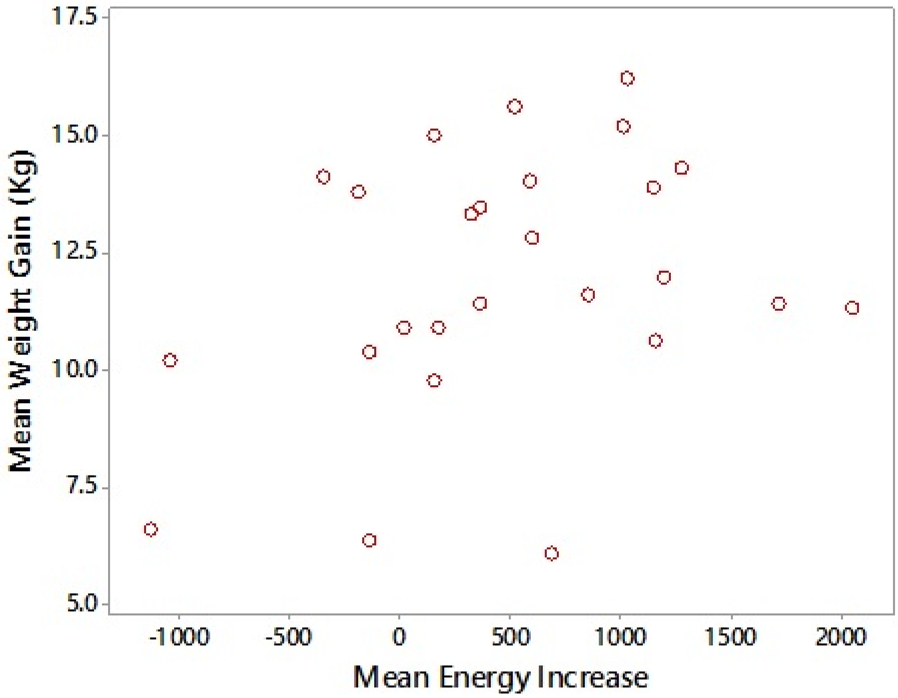

Figure 4 A. Exploring a correlation between mean difference in energy intake between early and late pregnancy and gestational weight gain. There is no significant correlation between mean energy increase and mean gestational weight gain at a 1% significance level (r = 0.321, *P* = 0.110).

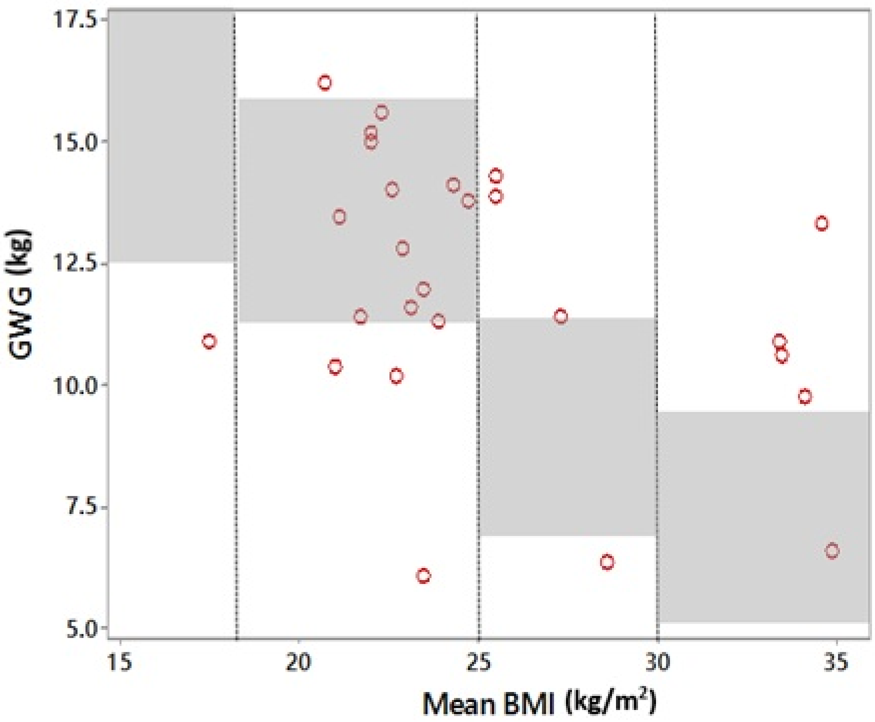

Figure 4 B. Scatterplot of gestational weight gain (GWG) compared to mean body mass index (BMI) for each study population. Shaded areas represent the Institute of Medicine guidelines for gestational weight gain (GWG) for each BMI category: underweight (BMI < 18.5 kg/m^2, GWG 12.5 to18 kg), normal (BMI 18.5 to 24.9 kg/m^2, GWG 11.5 to 15.5 kg), overweight (BMI 25.0 to 29.9 kg/m^2, GWG 6.5 to 11.5 kg) and obese (BMI ≥ 30 kg/m^2, GWG 5.0 to 9.0 kg).

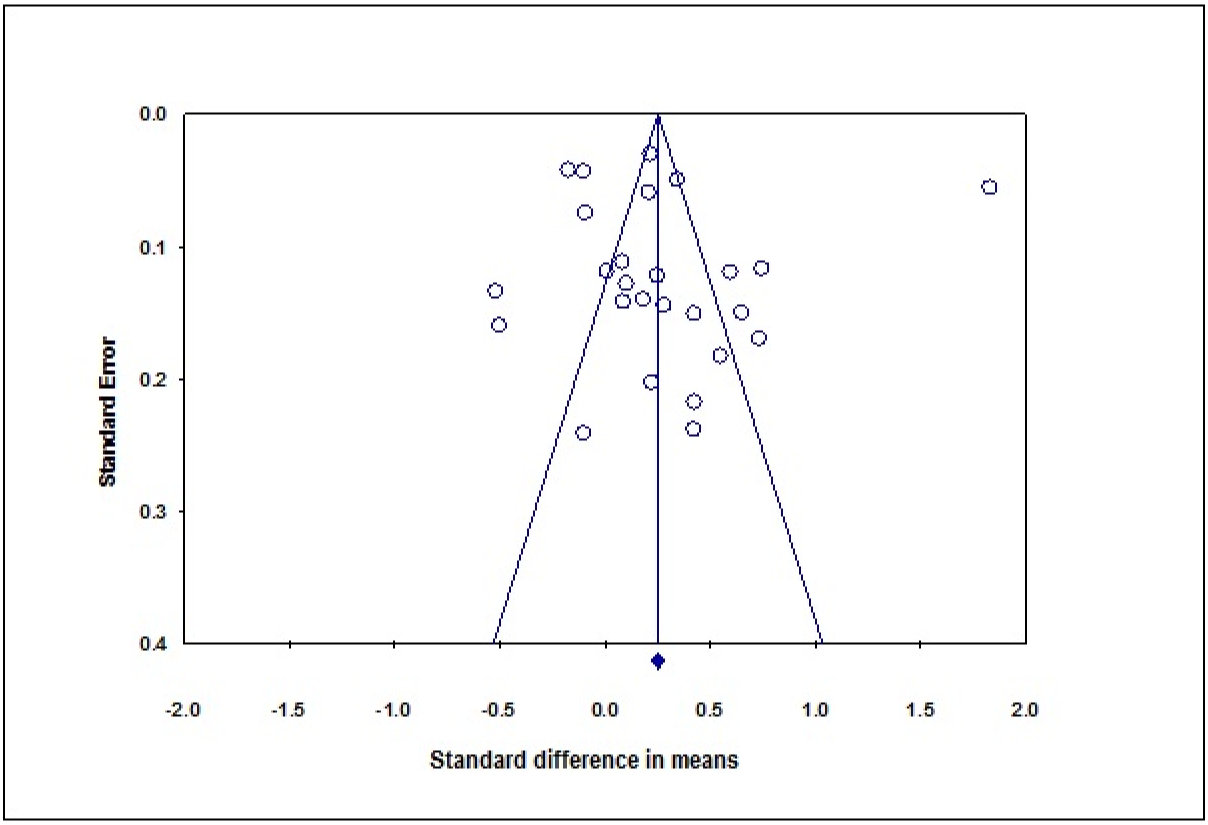

Figure 5 Assessing the risk of publication bias using standard error by standard difference in means from 14 observational studies and 4 randomized controlled trials. The solid angled lines indicate a triangular region where 95% of studies are expected to lie in the absence of both biases and heterogeneity and solid vertical line represents no intervention effect. Begg and Mazumdar's rank correlation was 0.163 (two-tailed p-value = 0.252) and Egger's regression intercept was 0.528 (two-tailed p-value=0.826).